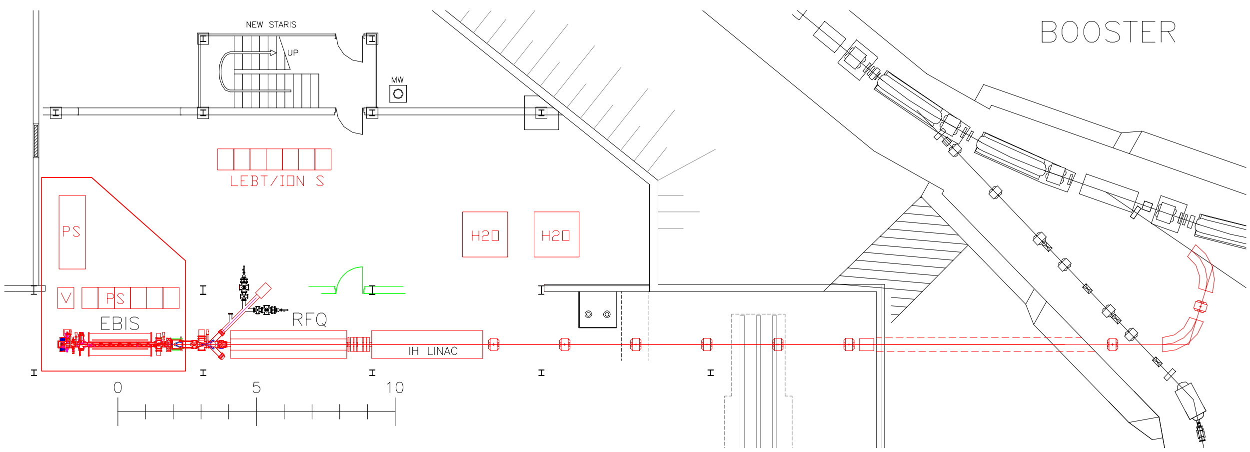
Electron Beam Ion Source (EBIS) Project

PRELIMINARY HAZARD ANALYSIS

1. Facility

The new heavy ion pre-injector facility for RHIC consists of three major pieces of equipment: 1) a high charge state Electron Beam Ion Source (EBIS), 2) a Radio Frequency Quadrupole (RFQ) accelerator, and 3) a short Linac. EBIS produces high-charge state ions at 17 keV per amu. The RFQ output energy is 300 keV per amu. The minimal final energy out of the short linac will be 2 MeV/amu, which is then injected into the AGS Booster. The high reliability and flexibility of this Linac-based pre-injector will be an essential component for the long-term success of the RHIC facility. A preliminary sketch of the facility is shown in Figure 1.

Figure 1 Schematic Showing the EBIS Pre-injector (in red) in the Lower Equipment Bay of the 200-MeV Linac



2. Location

The heavy-ion pre-injector, the Electron Beam Ion Source (EBIS), will be housed in the 200-MeV Linac, Building 930, with a short tunnel section connecting to the Booster. Injection into the Booster will occur at the same location as the existing injection from the Tandem.

3. Process or Activity Description(s)

The RFQ and linac that are used to accelerate beams from the EBIS to energy sufficient for injection into the Booster are both very similar to existing devices already in operation at other facilities.

The principle of operation of an EBIS is as follows. At one end an electron beam is produced, and then compressed to high density as it enters a strong solenoidal magnetic field. The beam passes through the solenoid, is decelerated, and then stopped in the electron collector. The EBIS trap region is a series of cylindrical electrodes in the main solenoid. Electrostatic barriers are produced on the ends of the trap region by applying positive voltages on the end electrodes. Ions are confined radially by the space charge of the electron beam. The trap is seeded either by injecting neutral gas of the desired ion-species, or by axial injection and trapping of singly charged ions produced in an external ion source. As the ions are held in the trap, they are step-wise ionized, until the desired charge state is reached, at which time the voltage on one end electrode is reduced and the ions are extracted. They pass axially through the electron collector and into a beam transport line.

The main features of EBIS include a 10 to 15 A 40-keV electron gun, an electron collector capable of dissipating a power of 300 kW, a cooling system, and a 6 T superconducting solenoid. As presently envisioned, the EBIS electron collector cooling system will dissipate heat from the collector by the flow of water through cooling channels in the collector. The 40-gallon per minute cooling system capacity of 400kW exceeds with good safety margin the maximum heat load running the EBIS in a DC mode.

Before the highly charged ions are expelled from the EBIS trap for transport to the RFQ, the EBIS platform voltage is pulsed on at from 34 kV to 100 kV, depending on ion charge to mass ratio, such that the extracted ion energy is ~17 keV per amu.

The Low Energy Beam Transport (LEBT) transports the ion beam from the EBIS and matches it to the RFQ. The layout was shown in Figure 1. The LEBT is ~1.4 meters long and consists of solenoid magnets or electrostatic lenses for transverse matching, transverse steerers, and a Y-chamber in the middle of the line. One arm of this chamber allows ions from an external ion source to be injected into the EBIS trap. In the second arm extracted ions can be deflected into a time-of-flight diagnostic.

The RFQ has four sections, (1) radial matching section, (2) shaper (3) buncher and (4) accelerating section. The RFQ length is ~4.4 meters. The RFQ transmission is greater than 80% even for currents in excess of 30 mA. The input beam energy to the RFQ is17 keV per amu and the output energy is 300 keV per amu.

The purpose of the Medium Energy Beam Transport (MEBT) is to match the beam from the RFQ to the Linac structure in all three planes (two transverse and one longitudinal).

The Linac section (presently envisaged as an Interdigital-H structure) will be a single-cavity designed for a fixed output velocity. The minimal final energy out of the linac will be 2 MeV/amu, which is then injected into the AGS Booster. The short linac has one tank, 4 meters long, with two quadrupole triplets inside for focusing. The maximum field on the axis will be 13.5 MV/m.

The High Energy Beam Transport (HEBT) matches beam transversely from the linac to Booster injection, minimizes the energy spread at the injection, provides ion charge state discrimination, and provides space for diagnostics

4. Inventory of Hazards

Ionizing Radiation – A portion of the EBIS Facilities are in the Booster Ring enclosure. The Booster Ring is a High Radiation Area during shutdown or maintenance days. The residual radiation level may be greater than 100 mrem per hour in these areas. Other locations for the EBIS Project equipment have lower-level residual radiation hazards, typically less than 5 mrem in an hour. Direct radiation from the operation of the EBIS, RFQ and short linac is expected to range between several mrem per hour in the nearby aisle way due to beam mis-alignment and several terarem per hour due to direct in-beam exposure. Thus, the beam will be fully enclosed by a vacuum pipe, which prevents direct exposure to beam. A second source of ionizing radiation will be x-rays produced primarily during voltage conditioning of the RFQ and linac accelerators. The vacuum walls of the RFQ enclosure provide sufficient shielding to reduce these x-rays to below 0.1 mrem per hour. Levels external to the linac vacuum enclosure are expected to be high enough that additional external shielding will be required to keep levels below 5 mrem per hour under all conditions.

Non-ionizing Radiation - High power RF systems that generate large fields of electromagnetic radiation in the frequency range of a few hundred kilohertz may be present.

Hazardous or Toxic Materials - Although the dominant shield materials are concrete and iron, lead shielding may be sparsely found in this location. Hazardous chemicals will include cleaning agents and water treatment chemicals.

Radioactive Materials – Various low-level radioactive materials will be present in the nearby shielding and accelerator equipment due to activation. Typically, the nuclides are ^{60}Co, ^{22}Na and ^{3}H, and they are found in pCi/g concentrations.

Fire - Welding gases and flammable/explosive gases may exist during construction or during repair periods. The personnel risks associated with the fire hazard are considered low. Emergency power and lighting are available in all locations for the EBIS Project and the maximum travel distance from any point to an exit is less than 300 feet.

Electrical Energy - Electrical hazards leading to personnel injury include electrical shock and high-voltage arcing. Equipment is normally de-energized prior to work.

Oxygen Deficiency - The cryogenic system for the EBIS solenoid contains a cryogenic liquid that can be released.

Kinetic Energy - Kinetic energy hazards associated with motorized materials-handling-equipment and with the operation of hand and shop tools will exist.

Potential Energy - High magnetic fields will be present and loose, ferrous objects will have to be located at a safe distance from the superconducting solenoid. Potential energy hazards such as those associated with compressed gases and vacuum windows, as well as those associated with hoisting and rigging operations will exist.

Thermal Energy - Heat sources such as soldering irons and vacuum heating blankets will exist.

Cryogenic Temperatures - Skin contact with cryogenic materials due to spills or splashes may cause freezing or "cryogenic burns."

5. Preliminary Hazard Analysis (PHA)

An initial review of environmental, safety and health issues related to EBIS facilities leads to the conclusion that fire, ionizing radiation, oxygen deficiency and electrical hazards require further safety analysis, which considers the preventive and mitigating facility design features. Collider-Accelerator Department and Brookhaven National Laboratory have specific programs that the EBIS Project must comply with in order to identify, analyze, design-out and/or control these hazards. For example:

- Accelerator Safety Subject Area
- ALARA Committee Review
- Accelerator System Safety Committee Review
- Area Risk Assessments
- Cryogenic Safety Sub-Committee Review
- Conduct of Operations
- Environmental Management System
- Facility Specific Training
- Hazard Screening Tool
- Job Risk Assessments
- OSH Management System
- Process Evaluations
- Radiation Safety Committee Review
- Work Controls for C-A Staff

In general, the following specific occupational safety and health techniques will be used in the order listed in order to reduce or eliminate the potential risks associated with fire, ionizing radiation, oxygen deficiency and electrical hazards in the EBIS facilities:

- Eliminate the hazard/risk
- Control the hazard/risk at source, through the use of engineering controls
- Minimize the hazard/risk through the use of safe work systems, which include administrative control measures such as check-off lists and work permits
- If residual hazards/risks cannot be controlled by the above measures, then use appropriate personal protective equipment, including clothing

Emergency issues will be addressed in the C-A OPM 3.0, Local Emergency Plan for the C-A Department.

Prior to work in EBIS facilities, key competency requirements are required to be met by technicians, scientists, guest, users and sub-contractors. A job training assessment (JTA) will be performed for every job category. Specific training will be listed in each person's training record, and training requirements will be checked by Work Control Coordinators prior to any work.